Simplifying and Optimizing Your Data Transfers

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NASA Advanced Supercomputing Division

Overview

- Data transfers using Shift
  - What is Shift?
  - Why should you use it?
- Basic transfer tasks
  - Copying files
  - Synchronizing directories
  - Creating/extracting tar files
- Optimizing transfer performance
  - Shift tuning options and when you should use them
- Common mistakes/misunderstandings
  - What they are and how to avoid them

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Self-Healing Independent File Transfer (Shift)

- What is it?
  - Automated file transfer mechanism
  - Supports local, intra-enclave, and remote transfers
  - Has facilitated transfers of > 40 PB of data since April 2012
- Why should you use it?
  - Unified interface with simple cp/scp syntax
  - Fire and forget transfers
    - Takes care of numerous details so you don't have to
    - Uses best practices by default
  - Advanced performance and reliability features
  - Saves you time and effort
    - Reduces transfer time
    - Reduces learning curve
    - Reduces manual transfer management

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Basic Transfer Tasks

Shift's Three Main Capabilities

- Copying files
- Synchronizing directories
- Creating/extracting tar files

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Copying Files With Traditional Tools

- Local transfers
  - **pfe%** cp /file1 /file2
- Intra-enclave transfers
  - **pfe%** scp /file1 lfe:/file2
- Remote transfers
  - **yourhost%** sup scp /file1 pfe:/file2

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Secure Unattended Proxy (SUP) Review

- What is it?
  - Mechanism that allows specific commands to be invoked on HEC front-ends from external systems without SecurID for up to a week
- Usage
  - Download "sup" (http://www.nas.nasa.gov/hecc/support/kb/file/9)
  - Make client executable (chmod 700 sup)
  - Move client to directory in your $PATH (mv sup ~/bin)
  - Authorize directories for writes on both pfes and lfes
    - **pfe%** echo /u/user > ~/.meshrc;
    - **pfe%** echo /nobackup/user >> ~/.meshrc
    - **pfe%** scp ~/.meshrc lfe:
  - Prepend "sup" to normal commands (sup scp file pfe:/nobackup/user)
- More information
  - http://www.nas.nasa.gov/hecc/support/kb/entry/145

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Copying Files With Shift

- Local transfers (just like "cp")
  - **pfe%** cp /file1 /file2
  - **pfe%** shiftc /file1 /file2
- Intra-enclave transfers (just like "scp")
  - **pfe%** scp /file1 lfe:/file2
  - **pfe%** shiftc /file1 lfe:/file2
- Remote transfers (just like "sup scp")
  - **yourhost%** sup scp /file1 pfe:/file2
  - **yourhost%** sup shiftc /file1 pfe:/file2
    - shiftc is embedded in sup client
    - All examples with "shiftc" can be done with "sup shiftc"

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Common Copy Options

- Recursive transfers (-r/-R/--recursive...just like cp/scp)
  - Copy directories recursively
- Symbolic link dereferencing
  - Never follow links (-P/--no-dereference...just like cp)
  - Always follow links (-L/--dereference...just like cp)
- Directory handling
  - Create missing parent directories (-d/--directory...just like install)
  - Treat target as a file (-T/--no-target-directory...just like cp/install)
- Secure remote transfers (--secure) (decreases performance)
  - Only use remote transports that encrypt data streams
  - Use more secure ciphers and MAC algorithms for ssh connections
- Feature disablement
  - Do not send status emails (--no-mail)
  - Do no preserve times, mode, ownership, xattrs, acls (--no-preserve)

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After Starting A Transfer

- Shift prints transfer id
  - "Shift id is 1"
  - The id can be used to manage/monitor a particular transfer
- Shift detaches and begins the transfer
  - "Detaching process (use --status option to monitor progress)"
  - You do not need to stay logged on to the origin system
  - You will be notified by email of completion, errors, and/or warnings (unless --wait or --no-mail specified)

Stopping/Restarting/Monitoring Transfers

- A running transfer may be stopped at any time from any host
  - shiftc --stop --id=N
  - Batches of file operations in progress will run to completion
- A stopped/failed transfer (state = stop/error) may be restarted
  - shiftc --restart --id=N
  - Completed operations will not be run again
  - Failed/unattempted operations will be retried/attempted
  - This is the best and fastest way to recover from transient errors
  - Must restart on original host or one with equivalent file system access
- Shift provides status and history of transfers
  - shiftc --status
  - shiftc --history
  - Transfer data only kept for one week after completion/error/stop

Transfer Status (--status)

```
pfe% shiftc --status
```

```
id | state | dirs | files |       file size |  date |  run |      rate
   |       | sums | attrs |        sum size |  time | left |
---+-------+------+-------+-----------------+-------+------+---------
 1 | done  |  0/0 |   1/1 |       92KB/92KB | 10/03 |   2s |    46KB/s
   |       |  0/0 |   0/0 |       0.0B/0.0B | 17:06 |      |
 2 | done  |  0/0 |   1/1 |       92KB/92KB | 10/03 |   8s |  11.5KB/s
   |       |  0/0 |   1/1 |       0.0B/0.0B | 17:06 |      |
 3 | done  |  1/1 |   2/2 |       99KB/99KB | 10/03 |   1s |    99KB/s
   |       |  4/4 |   0/0 |     198KB/198KB | 17:07 |      |
 4 | error |  1/1 |   1/2 |       92KB/99KB | 10/03 |   3s |  30.7KB/s
   |       |  0/0 |   0/0 |       0.0B/0.0B | 17:08 |      |
 5 | done  |  1/1 | 64/64 |   65.5GB/65.5GB | 10/03 |  29s |  2.26GB/s
   |       |  0/0 |   0/0 |       0.0B/0.0B | 17:09 |      |
```

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Detailed Transfer Status (--status --id=N)

```
yourhost% sup shiftc --status --id=2

state | op     | target                | size |  date | length |    rate
      | tool   | info                  |      |  time |        |
------+--------+-----------------------+------+-------+--------+-------
done  | cp     | lfe2:/u/user1/file1 | 92KB | 10/03 |     5s | 18KB/s
      | bbftp  | -                     |      | 17:06 |        |
done  | chattr | lfe2:/u/user1/file1 |    - | 10/03 |     1s |      -
      | sftp   | -                     |      | 17:06 |        |

yourhost% sup shiftc --status --id=4 --state=error

state | op    | target               | size |  date | length | rate
      | tool  | info                 |      |  time |        |
------+-------+----------------------+------+-------+--------+-----
error | cp    | /tmp/dir2/file2      |  7KB |     - |      - |    -
      | rsync | rsync: send_files    |      |       |        |
      |       | failed to open:      |      |       |        |
      |       | Permission denied    |      |       |        |
```

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Transfer History (--history)

```
pfe% shiftc --history

    id | origin               | command
   ---+--------------------+-----------------------------------------
     1 | pfe21.nas.nasa.gov | shiftc file1 /tmp/dir1
     2 | pfe21.nas.nasa.gov | shiftc --no-verify -p file1 lfe2:
     3 | your_localhost     | sup shiftc -r /tmp/dir1 lfe2:/tmp/dir2
     4 | your_localhost     | sup shiftc -r --secure lfe2:/tmp/dir2 .
     5 | pfe21.nas.nasa.gov | shiftc -r --hosts=4 bigdir1 /nobackup/user1/bigdir2
```

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Synchronizing Directories (--sync)

- Shift can synchronize directories like rsync
  - Files with same modification time and size at src and dst are skipped
  - Files that don't exist at the dst are copied
  - Files with differing time/size are checksummed and reconciled using partial transfers
- Force checksum verification using -I/--ignore-times (just like rsync)
- Target follows normal -r semantics
  - Source placed beneath target if target exists, renamed to target otherwise
  - To synchronize directory to same name, specify parent of desired destination
    - shiftc --sync -r /dir1 /dir1_parent (to sync /dir1 with /dir1_parent/dir1)
  - To synchronize to different name, use -T/--no-target-directory
    - shiftc --sync -r -T /dir1 /dir2 (to sync /dir1 with /dir2)
- Synchronizing to lou file systems can be very time-consuming
  - Files may need to be retrieved from tape to checksum

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Creating/Extracting Tar Files (--create-tar/--extract-tar)

- Transfer to/from tar file instead of transfer to/from directory
  - Uses high-speed transports underneath
  - Supports all standard Shift features (e.g. verification, parallelization, ...)
  - Recursive directory traversal (-r) implied (just like tar)
  - Up to 20x GNU tar performance on a single host
- Tar creation
  - tar cf dirfile.tar /some/dir /some/file
  - shiftc --create-tar /some/dir /some/file dirfile.tar
- Tar extraction
  - tar xf dirfile.tar /some/dir
  - shiftc --extract-tar dirfile.tar /some/dir
- Mutually exclusive with --sync
  - Not practical to change sizes of files within tar archives

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Remotely Creating/Extracting Tar Files

- Like normal Shift transfers, source(s) or target may be on a remote host
- Remote tar creation with local files
  - shiftc --create-tar /some/dir /some/file lfe:dirfile.tar
- Local tar creation with remote and local files
  - shiftc --create-tar lfe:/some/dir /some/file dirfile.tar
- Remote tar extraction from local files
  - shiftc --extract-tar dirfile1.tar dirfile2.tar lfe:/some/dir
- Local tar extraction with remote and local files
  - shiftc --extract-tar lfe:dirfile1.tar dirfile2.tar /some/dir

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Shift Tar Options

- Splitting files over multiple tar files (--split-tar)
  - Files larger than tape size are detrimental to lou file system
  - Tar files are split by default at 500 GB
    - Can be changed using --split-tar (e.g. --split-tar=2t) (disable with 0)
  - Split tars for "name.tar" are called "name.tar-i.tar" for i ≥ 1
    - Can all be extracted at once using "--extract-tar name.*tar"
- Creating table of contents (--index-tar)
  - Large tar files on lou will eventually be migrated to tape
  - See "ls -l" output of contents without retrieving from tape
    - Creates "name.tar.toc" or "name.tar-i.tar.toc" for each split i
  - See "msum --check-tree" output of contents without retrieving from tape
    - Creates "name.tar.sum" or "name.tar-i.tar.sum" for each split i
  - May become default in the near future

More Information on Basic Usage

- Knowledge base article
  - http://www.nas.nasa.gov/hecc/support/kb/entry/300
- Man page
  - "man shiftc" on any HEC front-end

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Optimizing Transfer Performance

Shift Transfer Optimization

- Shift behavior and correspondence to tuning options
- Tuning options you should care about
- Ways you can help Shift on your external system(s)

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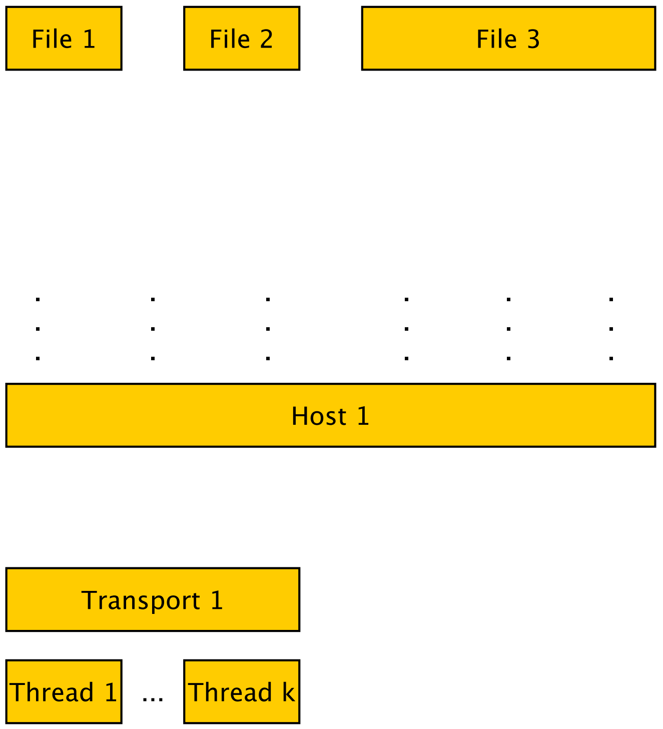
Traditional Transfers



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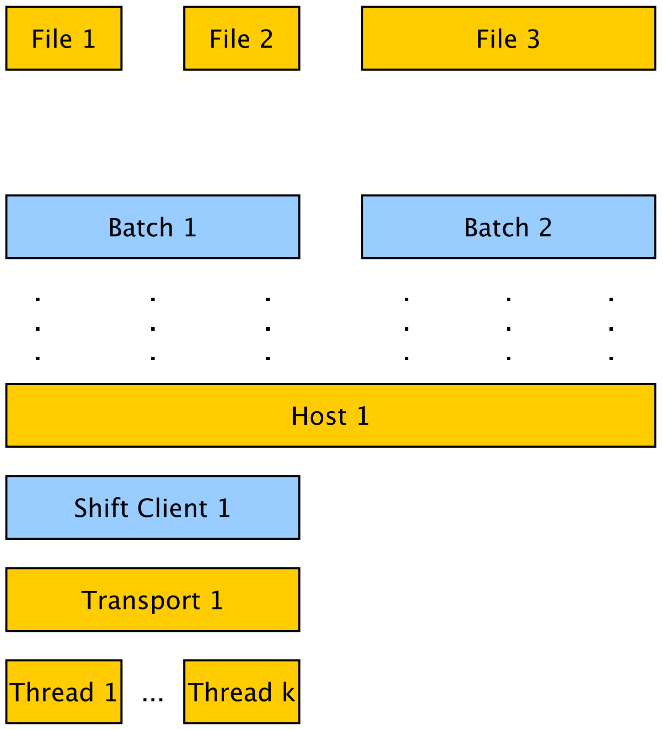
Shift Transfers



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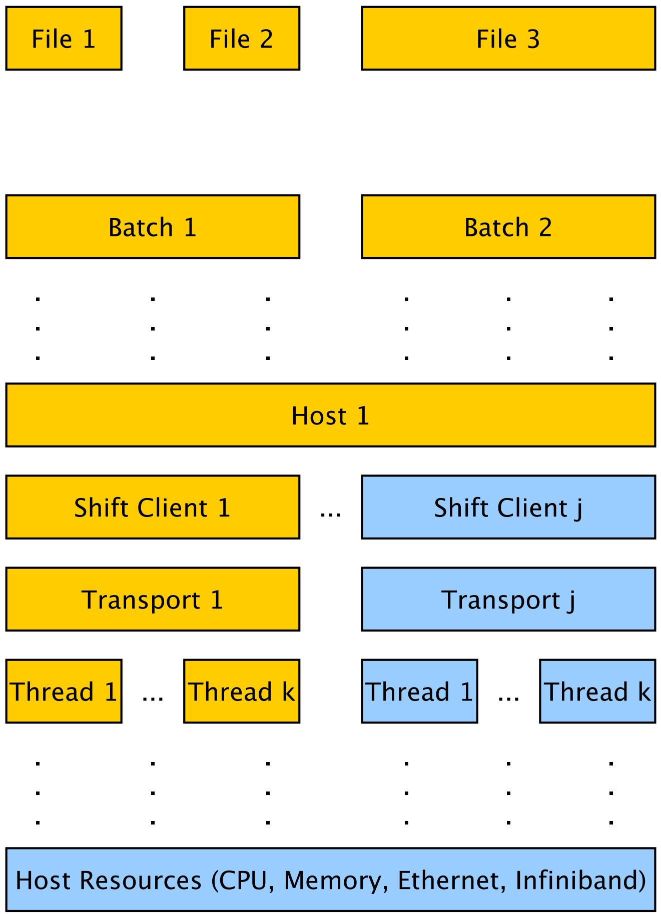
Shift Transfers With Multiple Clients



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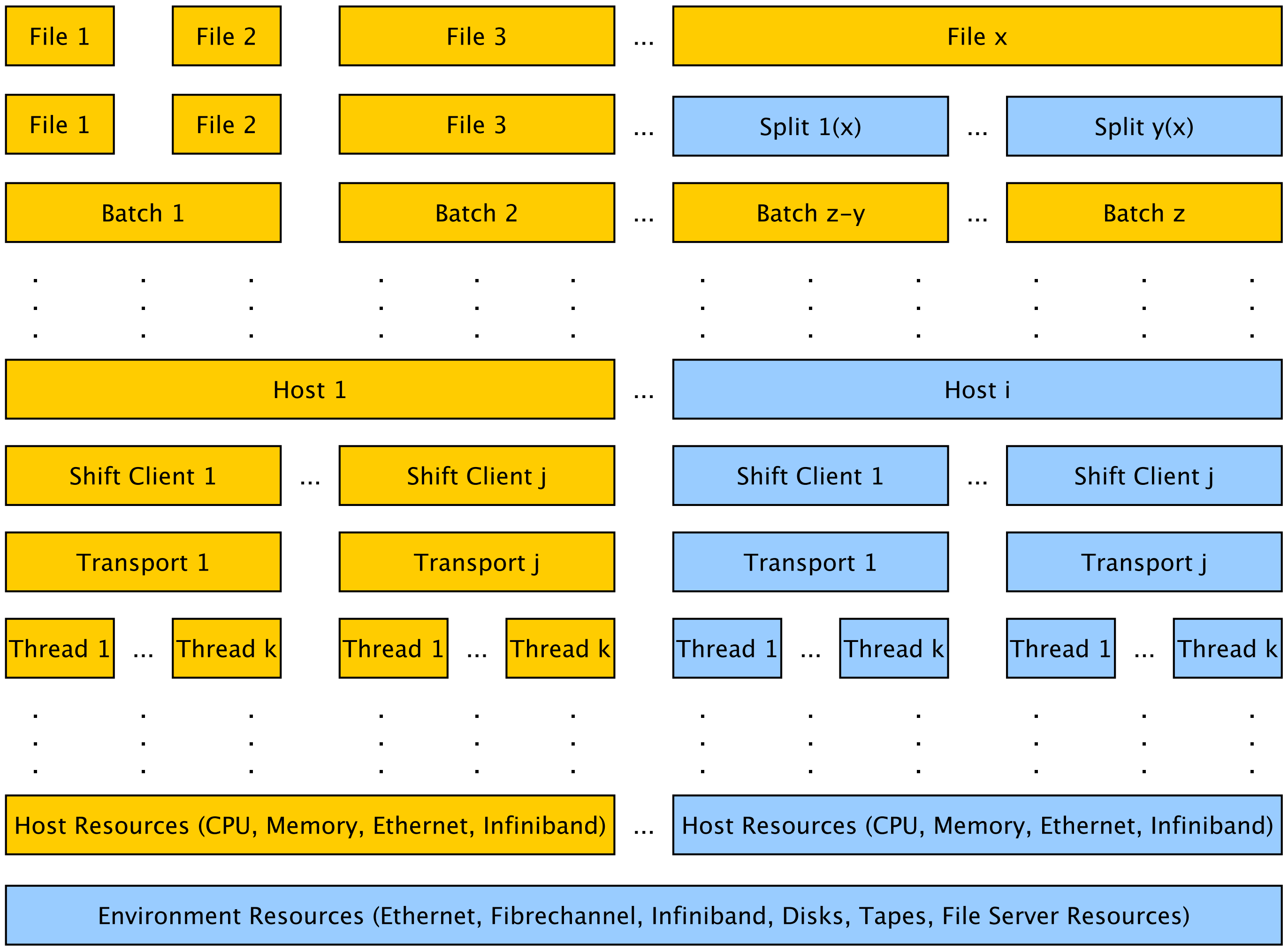
Shift Transfers With Multiple Hosts



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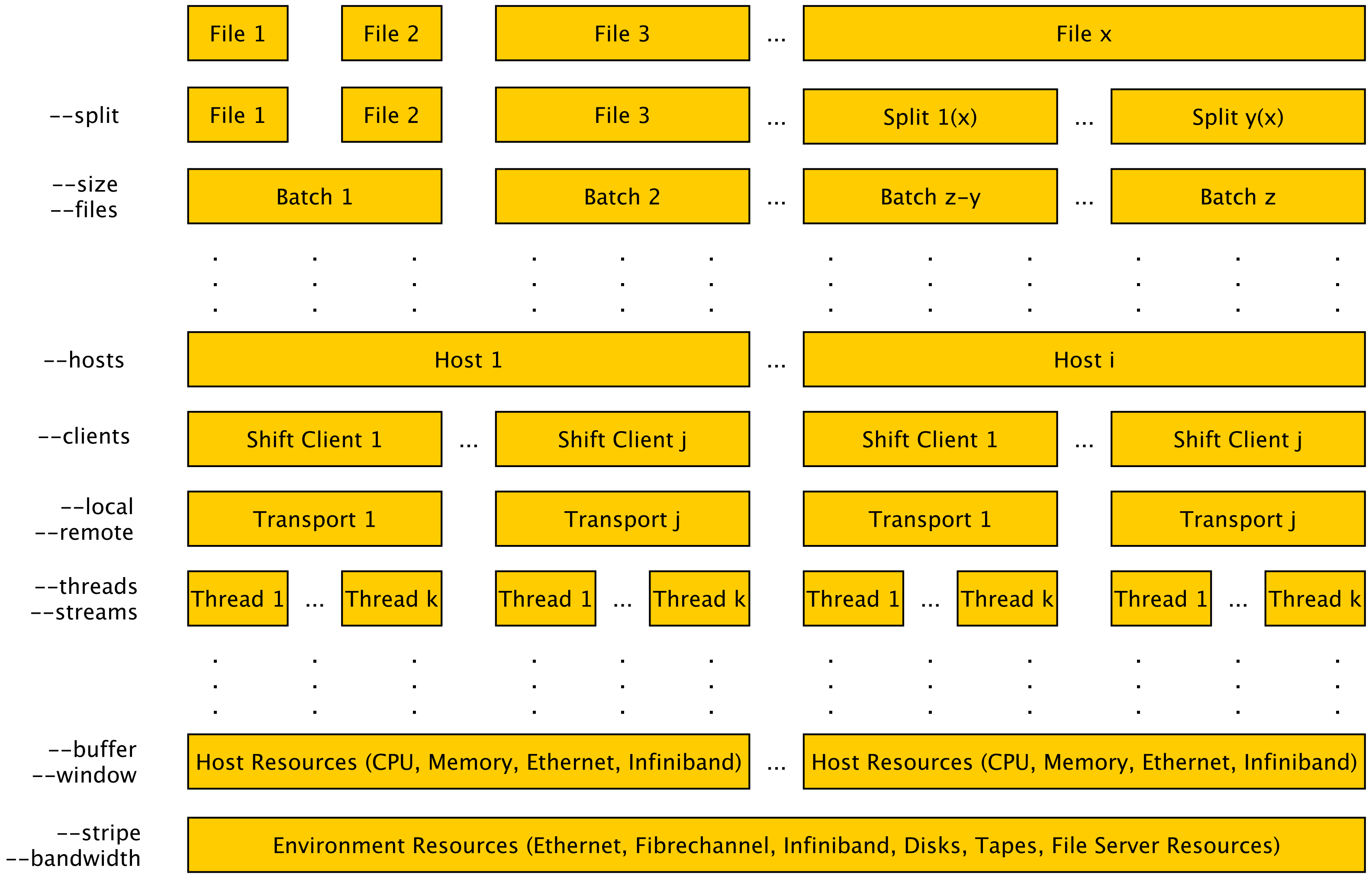
Shift Tuning Options



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That's A Lot Of Settings!

- The bad news
  - The number of settings can be overwhelming
- The good news
  - Shift takes care of most of them for you
    - Batch size set appropriately for default thread count
    - Transfers within NAS now parallelized on two hosts
    - Transports dynamically chosen to optimize each batch
    - Files striped to maximize write/future read performance
    - Buffer size set to reasonable value
    - Bandwidth approximated via heuristics
    - TCP window/streams set using bw/latency/OS limits

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Multiple Hosts (--hosts=N)

- Single easiest way to improve performance
- Within NAS
  - Default now --hosts=2
  - 6 user-accessible hosts mount cxfs (i.e. lou) (lfe/lsn)
    - More than 6 hosts has negative impact for transfers to/ from lou file systems
  - 22 user-accessible hosts mount lustre ([lp]fe/bridge/[lp]sn)
    - Lustre to lustre transfers can be done at very high speed
- Outside NAS
  - Src or dst must be on file system shared by multiple hosts at your site
  - More details later

File Splitting (--split=Ng)

- Multiple clients (on same or different hosts) are only effective if there is enough work to keep them busy
  - Large files can cause imbalances in client workload
  - Splitting allows large files to be processed by different clients
- Splitting is not currently enabled by default
  - Not compatible with bbftp and rsync
  - May be enabled in future since faster options are now available for both
- The split size should be set to at least the batch size
- It is beneficial to split the largest file into several times the number of total clients
  - Allows faster clients to process more than slower clients
  - Less work is lost if a client/host goes down for some reason

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Multiple Clients On A Single Host (--clients=N)

- Multiple clients were more useful before latest update
  - All built-in transports are now multi-threaded
- Two transports benefit most from this
  - Rsync is single threaded so multiple clients are the only way to parallelize its execution
  - Bbftp is multi-threaded but only operates on one file at a time so multiple clients allow it to parallelize across files
    - Detrimental to performance with big enough files (> 4 GB)
- Only use --clients when forcing these transports
  - --local/--remote=rsync or --local/--remote=bbftp
- All other transports perform better with increase in threads rather than clients

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Transport Thread Count (--threads=N)

- The default number of threads (4) is set low on purpose
  - At higher counts, a single transfer can exhaust a host's I/O bandwidth and impact all users
  - HEC front-ends are shared by all users for many purposes
- Higher thread counts are useful in lustre to lustre transfers
  - Within jobs on dedicated compute nodes – 32 threads achieves max
  - On front-ends – 8 threads is reasonable maximum
- Resist the temptation to increase threads on lou transfers
  - Lou front-ends are limited in number and often have higher loads
  - File system capacity is limited and migration constrained by tape speed
- Higher thread counts need bigger batches to keep threads busy
  - Batch size (--size) should be at least --threads GB

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Lustre Stripe Count (--stripe=N, --stripe=Ng)

- Shift automatically selects an appropriate stripe count for files transferred to lustre file systems
  - Does not work with bbftp due to use of temporary files
  - Shift preserves non-default striping when src also on lustre
- Two main reasons to touch this setting
  - You know the behavior of a parallel application that will access the data is optimized at a specific stripe count
    - Using --stripe=N will set stripe count of all files to N
    - Using --stripe=Ng will use one stripe per N GB
  - You have set the striping on the target directory and want to use default lustre striping behavior (--stripe=0)

Options That Help Shift (Remote Transfers)

- --bandwidth
  - Shift uses crude heuristics to guess your bandwidth
  - Specifying --bandwidth allows Shift to better optimize TCP window size and number of streams
    - For example, --bandwidth=10g
- --host-list
  - Shift remembers remote hosts you have invoked it on and their shared file systems for future --hosts invocations
  - You can more rapidly let Shift know about other hosts with equivalent file system access using --host-list
    - For example, --host-list=mycluster1,mycluster2,mycluster3
  - After first time, can just use --hosts

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Actions That Help Shift (Remote Transfers)

- Installing supported software
  - Shift can only use bbftp if installed and in your $PATH
    - http://doc.in2p3.fr/bbftp
  - New built-in fish-tcp transport outperforms bbftp in most cases so bbftp not as important as it used to be
    - Need perl >= 5.10.1 with threads (perl -V lgrep THREAD)
- Adjusting operating system TCP window settings
  - Keep TCP pipeline full while packets in flight
  - Determines max performance per TCP stream
    - max throughput = max window / latency
  - sysctl net.core.[wr]mem_max and net.ipv4.tcp_[wr]mem
    - 100MB for 10 Gb/s, 10MB for 1 Gb/s, 1MB for 100 Mb/s

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Common Mistakes/Misunderstandings

Remote Transfers

- Please install "sup" client as yourself in a writable location
  - Critical fixes are provided through built-in updates
    - Update when prompted – there was a reason for the update
    - Remote admins cannot easily track the need for updates
- Make sure ~/.meshrc exists and is configured on both the pleiades and lou home file systems
- A src/dst with "user@" currently does not do anything
  - Two options if remote/NAS user name differs
    - Use "sup -u NAS_user" on every invocation (or create shell alias)
    - Modify ~/.ssh/config (if not using NAS ssh template)
      - Host sup.nas.nasa.gov sup-key.nas.nasa.gov
        - User NAS_user
  - Will probably add better support for "user@" syntax in near future

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Parallel Remote Transfers

- --hosts has no effect unless you have multiple hosts on your side with access to transfer src or dst on shared file system
  - Use --host-list option first time so Shift can learn about other hosts
- You have multiple hosts but --hosts not working
  - Check all hosts in each other's ssh known hosts
  - All hosts must have "sup" in default $PATH
  - All hosts must be accessible via publickey or hostbased authentication
    - Have ssh agent running on origin if publickey authentication used
  - Can test these conditions with single command
    - ssh -oBatchMode=yes otherhost sup
      - "Host verification failed" – bad known hosts
      - "Command not found" – bad path
      - "Permission denied" – bad authentication
      - "Usage: sup" – setup is good so some other issue if not working

Many Transfers At Once

- Avoid starting many transfers on the same host at the same time
  - Even one transfer can potentially max out a host's resources
  - Many transfers can degrade performance significantly
- Two options
  - In scripts, can use --wait in between transfers
    - Next transfer only started when previous completes
  - Group transfers together under same Shift id using stdin
    - src(s) and dst, one per line
    - Command line options apply to all lines
    - echo "/file1 /dir1" > in; echo "/file2 /dir2" >> in; shiftc < in
    - Use --hosts to spread grouped transfers across systems

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A Transfer Is Not Done Until It Is "done"

- Do not remove src files before Shift reports "done"
- Wait for completion email or check status with --status
- Shift may process files in a different order than other tools
  - The existence of a particular file does not imply the existence of others
- Shift may operate on different portions of the same file at the same time
  - A file may show up with full size but still be incomplete

Ignore Errors At Your Peril

- A transfer ending in the "error" state is not complete
  - Files may not have been transferred or partially transferred
  - File integrity may not have been verified
    - Done files may show N/N but some files could be corrupt
  - File sanity checks may not have been completed
  - Tar renames may not have been completed
  - File attributes may be incorrect
    - File attributes are only preserved after its checksum stage
    - Dir attributes are only preserved after all files preserved
- A transfer in the "warn" state has operations that will be retried
  - Errors may be transient and correct themselves after retry

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Restart Is Your Friend

- Transfers ending in "error" state typically do not need to be rerun from scratch
- Shift provides a restart capability
  - shiftc --restart --id=N
  - Only failed operations will be retried
  - Many transfer options can also be respecified (see man page)
- Some errors are not recoverable
  - Src files that have been removed
  - Dst files that have been removed (mostly tar files but some other cases)
  - Src files that are still being written
  - Shift transfer metadata issues (mostly due to bugs)
- If a restarted transfer keeps failing and the reason is unknown
  - Email support@nas.nasa.gov

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Avoid Transfers Of Files Still Being Written

- Transfers of unstable files rarely complete due to constant mismatches of src/dst checksums
  - You may start ignoring errors thought to be due to changes
- If necessary, consider use of --include/--exclude
  - For example, changing files always named "bad.file"
    - --exclude='bad.file'

Inclusion/Exclusion

- File names may be explicitly included/excluded
  - Include only files matching given expression (--include)
  - Exclude files not matching given expression (--exclude)
  - May be specified multiple times
- Options take regular expressions – not wildcards
  - --include='foo*' matches 'fo{o,oo,ooo,...}', but not 'foo1'
  - Use '.*' in place of '*' for approximate conversion (e.g. 'foo.*')
  - See "man perlre" for advanced syntax

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Status Updates

- Status is only updated in between batches
  - Batches with large files take longer in between updates
    - Splitting allows status to be updated more frequently
- Retrieval from lou may require reads from tape
  - Done files can stay at 0/N for hours
  - Done files in tar extractions can stay at 0/0+ for hours
    - File count/size not known until tar file(s) back online
- If you don't think the transfer is doing anything
  - Find relevant host(s) with "shiftc --status --state=run --id=N"
  - Find transfer related processes on host(s) using "ps"
  - cat /proc/pid/io twice in succession to see if I/O being done
  - Shift may be sleeping before retry or waiting for other clients

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Conclusion

Conclusion

- You've hopefully learned
  - How to perform basic transfer tasks with Shift
  - When and how to use Shift tuning options effectively
  - Some common usage mistakes and how to avoid them
- Usage takeaway
  - Shift simplifies/automates/unifies copy/sync/tar of local/remote data
  - Shift takes care of transfer best practices for you
- Tuning takeaways
  - Use multiple hosts if available and split large files to keep clients busy
  - Avoid overloading a single host
- Mistakes takeaways
  - Install "sup" client in your own account in writable location
  - Wait until transfers "done", don't ignore errors, and recover with --restart

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Comments, Suggestions, Questions, Issues Welcome

- You can help make Shift better
  - Suggest features that would make your life easier
    - Some current features exist because users asked for them
  - Report bugs and/or other non-optimal behavior
    - User environments and use cases can be very different
    - May not even know a problem exists unless reported
  - Email to support@nas.nasa.gov
- You can even use Shift at your site
  - Available as open source (http://shiftc.sf.net)
    - Latest version will be available in week or two

Question? Use the Webex chat facility to ask the Host